EEE407 - Renewable Energy
Week 2: Fundamentals of Energy, Transformations, and Units

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Energy and Power

Energy: The capacity to do work. [Unit: Joule (J)]
Power: The rate of transformation of energy. [Unit: Watt (W)]

$$Power = \frac{Energy}{Time}$$

Unit	Abbreviation	Conversion (J per unit)
Joule	J	1
Watt-hour	Wh	3,600 J/Wh
Calorie	Cal	4.18×10^{3} J/Cal
Barrel of Oil Equivalent	boe	6.1×10^{9} J/boe
Tonnes of Oil Equivalent	toe	4.19×10^{10} J/toe
British Thermal Unit	Btu	1,055 J/Btu

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Unit	Abbreviation	Conversion (Watts per unit)
Watt	W	1
Horsepower	hp	746
Kilowatt-hour per day	kWh/d	42
British Thermal Units per day	Btu/d	0.01

Energy

Types of Energy

- Electrical Energy
- Mechanical Energy
- Potential Energy
- Kinetic Energy
- Thermal Energy
- Magnetic Energy
- Radiation Energy
- Nuclear Energy
- Chemical Energy

Energy

Primary Energy

- Original energy, not yet processed
- Crude oil, uranium, solar radiation, and wind

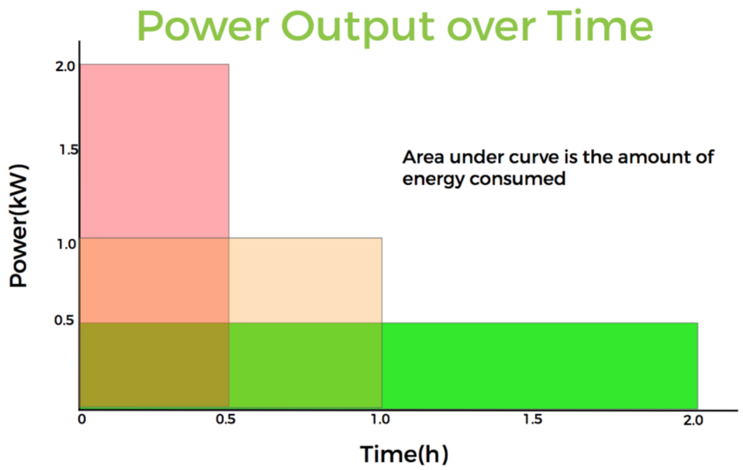
Final Energy

- Energy in the form that reaches the end user
- Gas, fuel oil, petrol, electricity, hot water or steam

Effective Energy

- Energy in the form used by the end user
- Light, radiator heat, driving force of machines or vehicles

Energy



Energy - Examples

How much electrical energy does a 1.5 kW solar panel, which is working at full capacity, produce in 5 hours?

- Answer: 7.5 kWh

How long does a 1.5 kW solar panel need to work at full capacity for to power a 1,000 W microwave for 10 minutes?

- Answer: 400 s

Temperature and Heat

Temperature is proportional to the average kinetic energy of the particles of matter.

- Celsius (°C)
- Fahrenheit (°F)
- Kelvin (K)

Celsius to Fahrenheit conversion:

$$T_F = 1.8 \times T_C + 32$$

Celsius to Kelvin conversion:

$$T_K = 273.15 + T_C$$

Numerical Prefixes

Prefix	Symbol	Size
Milli	m	10^{-3} (thousandth)
Micro	μ	10^{-6} (millionth)
Nano	n	10^{-9} (billionth)
Pico	p	10^{-12} (trillionth)
Femto	f	10^{-15} (quadrillionth)
Atto	a	10^{-18} (quintillionth)
Kilo	k	1,000 (thousand)
Mega	M	1,000,000 (million)
Giga	G	1,000,000,000 (billion)
Tera	T	10^{12} (trillion)
Peta	P	10^{15} (quadrillion)
Exa	E	10^{18} (quintillion)

Efficiency

Efficiency is the ratio of the useful work performed or energy output to the total energy input and is expressed as a percentage.

$$\eta = \frac{Energy\ Output}{Total\ Energy\ Input} \times 100$$

Carnot efficiency is the maximum possible efficiency of a given energy system that converts heat to useful work.

$$\eta_c = (1 - \frac{T_c}{T_h}) \times 100 = \frac{(T_h - T_c)}{T_h} \times 100$$

where η_c is Carnot efficiency, T_c is the coldest and T_h is the hottest system temperature measured in Kelvin.

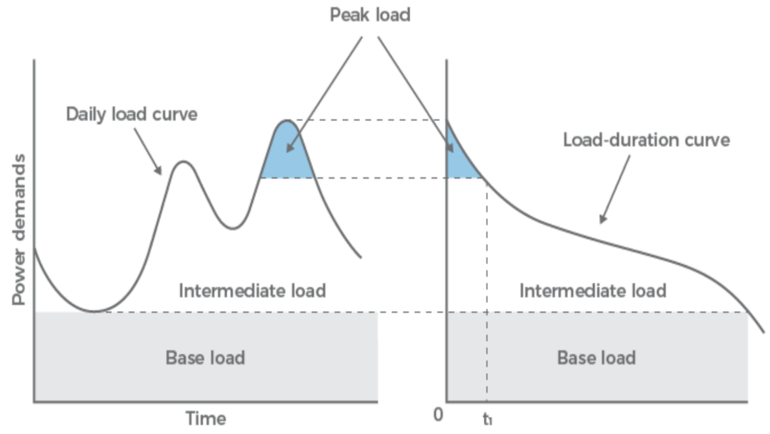
Capacity Factor

Factors that stop a producer from generating to their full capacity may be things that are within their control, such as a choice to reduce generation based on fuel costs or decreased power demand or they may be factors that are outside their control such as weather conditions or available sunlight.
Regardless of the cause, capacity factor is calculated using the equation below

$$Capacity\ Factor = \frac{Actual\ Power\ Output}{Nameplate\ Capacity} \times 100$$

Capacity factor is the actual output divided by the nameplate capacity.

Electric Load Profiles



Emissions

The formula to calculate tonnes of CO_2 equivalent is shown below

$$Tonnes\ \ of\ \ CO_2\ \ eq = GWP \times Mass$$

where GWP stands for global warming potential and $Mass$ represents the corresponding mass of greenhouse gases in tonnes.

The Kaya identity is an equation that helps to analyse the driving forces behind CO_2 emissions.

$$CO_2 = \frac{Emissions}{Energy} \times \frac{Energy}{GDP} \times \frac{GDP}{Population} \times Population$$

where GDP stands for gross domestic product.

More Examples

What is the electrical efficiency of a coal fired power station that produces 740 MW of electricity from 8,000 tonnes per day of coal? The coal has a calorific value of 22 GJ/t.

- Answer: 36%

How much energy from the sun is needed to produce 4.5 kWh of electricity, if the solar panels have an efficiency of 18%?

- Answer: 25 kWh

Imagine a gas turbine is being used to produce electricity. The top flame temperature is 800 °C and the lower cycle temperature is 25 °C. What is the Carnot efficiency of the system if it is considered to be an ideal heat engine?

- Answer: 72%

Concluding Remarks

The creator of this lecture note respects and obeys copyright issues strictly and notes that these slides are adapted into LaTeX Beamer from the sources as follows

- Smart, S., ENGY0x: Energy Principles and Renewable Energy Course of the University of Queensland (UQ), Australia which is a part of UQx's Sustainable Energy MicroMasters Program, EdX, 2020.
- Quaschning, V., Understanding Renewable Energy Systems, Earthscan, 2005.